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Opower

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[54] **APPARATUS FOR REMOVING MATERIAL FROM A TARGET**

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[51] **Int. Cl.⁵** **H01S 3/08**

[52] **U.S. Cl.** **372/108**; 372/22; 372/41

[58] **Field of Search** 372/10, 12, 18, 22, 372/41, 108; 359/328

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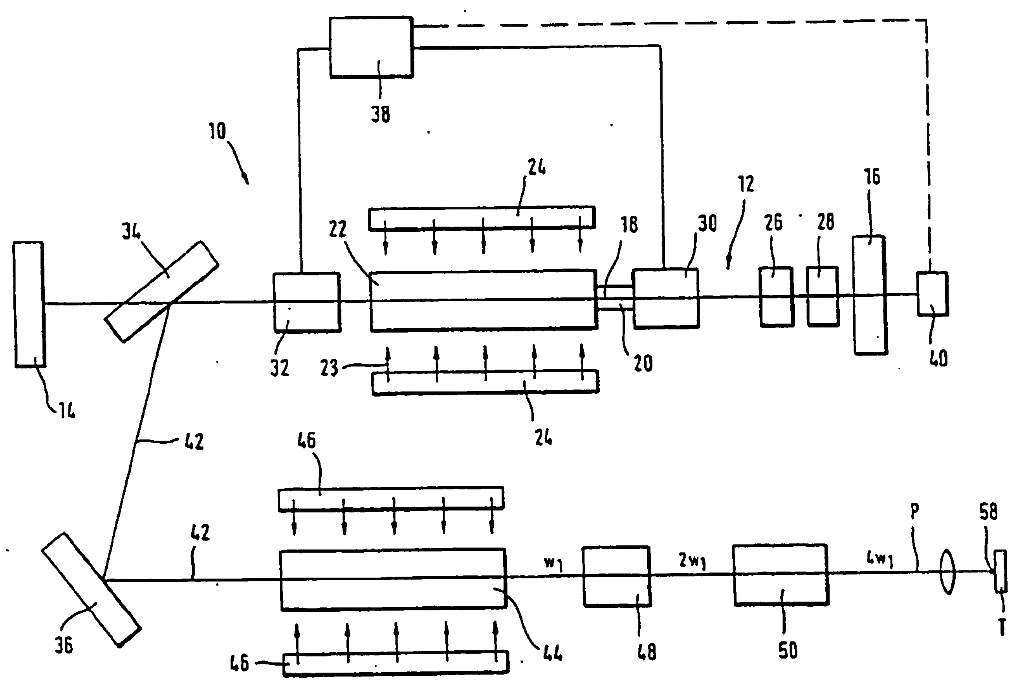
[57] **ABSTRACT**

In order to improve an apparatus for removing material from a target, comprising a high-power laser generating laser pulses with a pulse duration in the picosecond range and comprising a resonator, in which a mode-locking device and a Q-switch are arranged, a frequency multiplier following the high-power laser and a beam guide for focusing the laser beam coming from the frequency multiplier onto the target, such that the energy in the single laser pulses having a pulse duration in the picosecond range is as high as possible, it is suggested that the resonator have fully reflecting end mirrors for generating single high-energy laser pulses, that a system for the controlled coupling out of single pulses be arranged in the resonator and that a control be provided for coupling out a single pulse following release of the laser activity by the Q-switch and the build up of the single pulse after repeated round trips through the resonator.

28 Claims, 4 Drawing Sheets



In order to achieve a uniform removal of target material, for example, from the individual target 130*b* with the laser pulses P, the radiation spot 132 is movable on the target surface 136, for example, along a line 144 and preferably transversely thereto, as well. This can be achieved by the deflecting mirror 124 deflecting the laser beam 28 such that the radiation spot 132 migrates relative to the target carrier 126 along the line 44 and, where necessary, transversely to it.

Therefore, the cone 138, and with it the coating spot 142, also migrates to a slight extent on the surface 140 but the distance is not normally sufficient to achieve a full surface coating of the surface 140.

For this reason, a substrate holder 104 of a positioning table 102 displaceable on guides 108 is preferably movable, in addition, in an XZ plane relative to a base unit 106 so that the coating spot 142 migrates over the entire surface 140.

Alternatively, it is also possible to move the target carrier 126 by means of a displacing and positioning unit such that when the substrate 112 is stationary or the surface 140 is stationary the cone 138 and the coating spot 142 migrate over the entire surface 140, with corresponding following guidance of the laser pulses P by means of the deflecting mirror 124. In this respect, the relative movement of the radiation spot 132 on the target surface 136 relative to the individual target 130*b* is also to be taken into consideration during the following guidance.

The inventive system can, for example, also be used for the process according to German patent 40 22 817.

The present disclosure relates to the subject matter disclosed in German application No. P 42 29 397.9 of Sep. 3, 1992, the entire specification of which is incorporated herein by reference.

What is claimed is:

1. An apparatus for removing material from a target, comprising:

a high-power laser for generating laser pulses with a pulse duration in the picosecond range and comprising a resonator having a mode-locking device and a Q-switch arranged therein,

a frequency multiplier following the high-power laser, and

a beam guide for focusing the laser beam coming from the frequency multiplier onto the target,

said resonator having fully reflecting end mirrors for generating single high-energy laser pulses, a system for the controlled coupling out of single pulses being arranged in the resonator, and a control being provided for coupling out a single pulse following release of the laser activity by the Q-switch and the build up of the single pulse after repeated round trips through the resonator.

2. Apparatus as defined in claim 1, wherein the control activates the single-pulse coupling-out means within a defined period of time following release of the laser activity by the Q-switch.

3. Apparatus as defined in claim 1, wherein the control activates the single-pulse coupling-out means when the single pulse building up in the resonator reaches an intensity threshold value.

4. Apparatus as defined in claim 1, wherein the single-pulse coupling-out means comprises a polarization-rotating Pockels cell and a polarization-dependent transmission/reflection mirror.

5. Apparatus as defined in claim 1, wherein a laser amplifier is arranged between the high-power laser and the frequency multiplier.

6. Apparatus as defined in claim 1, wherein the frequency multiplier is followed by a coupling-out element for a part of the laser pulse not frequency-multiplied.

7. Apparatus as defined in claim 6, wherein a beam guide is provided for focusing the non-frequency-multiplied part of the laser pulse onto the target.

8. Apparatus as defined in claim 7, wherein the frequency-multiplied part of the laser pulse and the non-frequency-multiplied part of the laser pulse are focused onto the target with separate beam guides.

9. Apparatus as defined in claim 6, wherein the non-frequency-multiplied part of the laser pulse strikes the target with a time delay in relation to the frequency-multiplied part of the laser pulse.

10. Apparatus as defined in claim 9, wherein the beam guide for the non-frequency-multiplied part of the laser pulse comprises a detour line for the pulse delay.

11. Apparatus as defined in claim 6, wherein a colinearizing element is provided for bringing together the frequency-multiplied part of the laser pulse and the non-frequency-multiplied part of the laser pulse.

12. Apparatus as defined in claim 11, wherein the colinearizing element is followed by a common focusing system for the frequency-multiplied part of the laser pulse and the non-frequency-multiplied part of the laser pulse.

13. Apparatus as defined in claim 6, wherein the frequency-multiplied part of the laser pulse and the non-frequency-multiplied part of the laser pulse form a defined pulse sequence.

14. Apparatus as defined in claim 1, wherein the laser pulse comprises a part of the laser pulse repeatedly frequency-multiplied.

15. Process for removing material from a target, wherein:

laser pulses with a pulse duration in the picosecond range are generated by a high-power laser comprising a resonator having a mode-locking device and a Q-switch arranged therein and multiplied by a frequency multiplier following the high-power laser,

the laser beam coming from the frequency multiplier is focused onto the target by a beam guide,

a high-energy single laser pulse is used as the laser pulse, this laser pulse being generated when the laser activity in the resonator is released by the Q-switch,

following the release of the laser activity a single pulse runs back and forth repeatedly between fully reflecting end mirrors of the resonator and a high-energy single pulse is thereby built up, and

the high-energy single pulse is coupled out by means of a system for the controlled coupling out of single pulses.

16. Process as defined in claim 15, wherein the single-pulse coupling-out means is activated within a defined period of time following release of the laser activity by the Q-switch.

17. Process as defined in claim 15, wherein the single-pulse coupling-out means is activated when the single pulse building up in the resonator reaches an intensity threshold value.

18. Process as defined in claim 15, wherein a polarization-rotating Pockels cell and a polarization-dependent

transmission/reflection mirror are used as single-pulse coupling-out means.

19. Process as defined in claim 15, wherein a laser amplifier is used between the high-power laser and the frequency multiplier.

20. Process as defined in claim 15, wherein a part of the laser pulse not frequency-multiplied is coupled out following the frequency multiplier.

21. Process as defined in claim 20, wherein a non-frequency-multiplied part of the laser pulse is focused onto the target with a beam guide.

22. Process as defined in claim 21, wherein the frequency-multiplied part of the laser pulse and the non-frequency-multiplied part of the laser pulse are focused onto the target with separate beam guides.

23. Process as defined in claim 20, wherein the non-frequency-multiplied part of the laser pulse is applied to the target with a time delay in relation to the frequency-multiplied part of the laser pulse.

24. Process as defined in claim 23, wherein the non-frequency-multiplied part of the laser pulse is applied to the target via a detour line for the pulse delay.

25. Process as defined in claim 20, wherein the frequency-multiplied part of the laser pulse and the non-frequency-multiplied part of the laser pulse are brought together by a colinearizing element.

26. Process as defined in claim 25, wherein the frequency-multiplied part of the laser pulse and the non-frequency-multiplied part of the laser pulse are brought together by a common focusing system following the colinearizing element.

27. Process as defined in claim 20, wherein a defined pulse sequence is formed with the frequency-multiplied part of the laser pulse and the non-frequency-multiplied part of the laser pulse.

28. Process as defined in claim 15, wherein the laser pulse is formed with a part of the laser pulse repeatedly frequency-multiplied.

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